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A method for improving energy utilization in 4-stroke piston engines

A method for a four-stroke piston engine, in which less working gas is sucked in during the intake stroke than would be possible based on the swept volume [or displacement] of the piston.

The working gas is then compressed to the hitherto customary compression pressure, which results in an increase in the compression ratio.

Such an engine can now utilize the full swept volume during the working stroke in discharging the working gases and thus discharge a greater volume of gases than on hitherto customary engines.

By this means the amount of energy dissipated via the outlet is reduced, which is directly related to thermal efficiency.

PATENT CLAIMS

1. A method for improving the thermal efficiency of 4-stroke piston engines.

This method is characterized in that an engine designed in accordance with this method sucks in less working gas during the intake stroke than would be possible than that based on the swept volume of the piston. This means, that such an engine operates with a charging ratio of less than 1.

However, the working gas is then compressed to the hitherto customary compression pressure, which results in an increase in the compression ratio.

This engine can now utilize the full swept volume during the working stroke in discharging the working gases and thus discharge a greater volume of gases than on hitherto customary engines.

2. The method according to Claim 1

is characterized in that the reduction in the induction volume and the thereby prolonged expansion are achieved by means of changes in the control times.

Description

A method for improved utilization of energy on 4-stroke piston engines.

The invention is a method of improving the thermal efficiency of 4-stroke piston engines with at least one working cylinder.

The thermal efficiency of 4-stroke engines is derived from the energy dissipated by an engine and the energy supplied to the engine during the cyclic process. The formula for thermal efficiency is:

$$\eta\, th = 1 - Q_{ab} / Q_{zu}$$

Therefore, in order to achieve a high efficiency,
Q_{zu} (energy supplied to the engine) must be as large as possible,and
Q_{ab} (energy dissipated by the engine) must be as small as possible.
The latter is the quantity of energy, which passes unutilized through the outlet. The purpose of this invention is to utilize this quantity of energy so far as is possible.
On current fast-running engines, such as are used e.g. to automobile drives, the discharged gas has a pressure of 3 – 5 bar and a temperature of around 800° - 1000° K, which corresponds to a quantity of energy of around 300 – 500 KJ/Kg. This is not an inconsiderable amount of energy.

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1. A device, which is currently known to partly utilize this unutilized quantity of energy is the exhaust gas turbocharger, which does not, however, directly convert this energy into useful work, but uses it to supercharge the working medium.

Dubbel Taschenbuch für den Maschinenbau, 14th Edition (Dubbel Pocketbook of Mechanical Engineering)
Springer Verlag, Berlin, Heidelberg, New York, 1981, pp. 791 – 804

Wolfgang Kalide
Energieumwandlung in Kraft- und Arbeitsmaschinen (Energy Conversion in Engines and Machines), 6th Edition, 1982
Carl Hanser Verlag, Munich, Vienna, pp 136-178

K. Löhner
Die Brennkraftmaschine (The Internal Combustion Engine)
VDI Verlag, Düsseldorf, 1963, p. 8

In this method, in which the discharged energy is used for supercharging, an undesirable heating of the working gas is unavoidable; therefore in most cases a large part of the recovered energy is discharged [or dissipated] again via a separate charge air cooling system.

- sheet 3 –

2. A further possibility of partially using this unutilized quantity of energy is the compound engine.
This is mostly a 2-stage engine, consequently also with a 2-stage expansion. The delivery of power takes place on the respective shafts of the two stages.

Lueger Lexikon der Technik, (Dictionary of Technology) Vol. 7,
Editor: Hermann Franke
Deutsche Verlagsanstalt, Stuttgart, 1965, p. 473

K. Löhner
Die Brennkraftmaschine (The Internal Combustion Engine)
VDI Verlag, Düsseldorf,
1963, p. 8

Due to the high costs of construction, this method is barely economical. Also, the coupling of the two stages presents difficulties if only one power-consumer [or load] is available.

The purpose of the invention is:
To directly convert a part of the unutilized energy, which is discharged via the outlet, into useful work.

In accordance with the invention, this task is solved in that the working gas, which after the energy has been supplied and discharge has occurred down to as close as possible to atmospheric pressure, requires more volume than it occupied before the energy transfer. This working gas is now provided with a relatively larger volume, which is achieved by a reduction in the quantity of gas taken in [or sucked in].

- sheet IV –

Thus the engine intentionally operates with a poor charging ratio.

The poor efficiency of previously constructed engines with a poor charging ratio, in specific load situations, is due to the low compression pressure, which is also the case here. The compression ratio cannot be increased in other load situations due to the danger of engine pinging [or pinking] (on spark ignition engines). However, in the method invented by me this is possible without risk, because the charging ratio is reduced in all load situations, so that the compression ratio can be increased in order to achieve a previously customary (pinging-free) compression pressure.

In my opinion, the reduced charging ratio on induction is achieved by means of changed control times, i.e.: The inlet valve opens at the previously customary point in time (in order to obtain a clean scavenging with fresh gas) but closes at an earlier point in time. Also, it is necessary to change the outlet valve control times for better energy utilization, since after completion of the working stroke the pressure in the cylinder is relatively low at the piston bottom dead center and the outlet valve needs to be opened very shortly before or at the piston bottom dead center.

The advantages obtained by means of the invention are realized, in particular, in a reduction in fuel consumption on an engine designed in accordance with the invention. This reduction in fuel consumption is achieved by very simple and inexpensive means. Such an engine requires no additional components. The modified components (in particular the camshaft) have only to be changed dimensionally.

- sheet V –

A further advantage lies in the simplified silencing [or muffling], due to the lower exhaust pressure.

In addition, this method can be equally well applied to the Otto and Diesel cycles.

The performance per litre of engine capacity of such an engine would be reduced at a given rpm, because the useful work as indicated by the p/v diagram is less. However, this reduced power remains within reasonable limits and can be compensated by increasing the swept volume [or displacement] of the piston (approx. 50%). In practice, one would therefore replace an engine in a production series of a given power with an engine equipped in accordance with the invention, but having a larger piston swept volume [or displacement].

Embodiment

With the embodiment, I am using a process of comparison, since computed process data can be used and the fundamental considerations in this invention can be related to the actual process.

A current 4-stroke Otto engine is taken as the basis of the comparison, the results of which are presented in Diagram 1.
This engine has the following process data:

Pressures:
$p_1 = 1$ bar
$p_2 = 18.4$ bar
$P_3 = 55$ bar
$P_4 = 3$ bar

Temperatures:
$t_1 = 340\ °K$
$t_2 = 781\ °K$
$t_3 = 2338\ °K$
$t_4 = 1017\ °K$

Volumes:
$V_1 = V_4 = 500\ cm^3$
$V_2 = V_3 = 62.5\ cm^3$
$V_h = V_1 - V_2 = 437.5\ cm^3$

Compression ratio:
$\varepsilon = 8/1$

Useful work:

$W = 323$ Nm

Thermal efficiency:

$\eta_{th} = 56.5$ %

Control times:

Inlet opens 8° before TDC

Inlet closes 43° after BDC

Outlet opens 43° before BDC

Outlet closes 8° after TDC

Advanced ignition: 30° before TDC at n = 3000 rpm (1/min)

These process data have been calculated on the basis of the isentropic process, with $\gamma = 1.4$.

The following changes are now made to this engine:

Control times:

Inlet opens 6° before TDC

Inlet closes 79° before BDC

Outlet opens 5° before BDC

Outlet closes 6° after TDC

Advanced ignition: 29° before TDC at n = 3000 rpm (1/min)

Compression ratio:

$\varepsilon = 13/1$

Volumes:

$V_h = 437.5\ cm^3$ (unchanged)

$V_1 = V_4 = 474\ cm^3$

$V_2 = V_3 = 36.5\ cm^3$

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The following process data are now calculated from the above:

Pressures:

$p_1 = 0.5$ bar

$p_2 = 18.1$ bar

$P_3 = 55$ bar

$P_4 = 1.5$ bar

Temperatures:

$t_1 = 280\ ^\circ K$

$t_2 = 780\ ^\circ K$

$t_3 = 2369\ ^\circ K$

$t_4 = 846\ ^\circ K$

Useful work:

$W = 217$ Nm

Thermal efficiency:

$\eta_{th} = 64.5\%$

The comparison process for the worked example is presented in Diagram 2.

The basis of the calculations was an exhaust pressure of 1.5 bar
This must not be much lower at full load, so that at partial load it does not drop below 1 bar, if possible.
A value was now sought by calculation for the initial pressure, with unchanged ignition and compression pressure.
A value of 0.5 bar was obtained.

- sheet IV –

From the results the angle for the closing of the inlet valve was obtained for a suction partial pressure of 0.15 bar (corresponding to 0.85 bar absolute). The reduced overlap resulted from a much-reduced residual volume at the TDC.
It should be pointed out, that such data can only provide an indication.

These data must be investigated in practical tests and determined on the test stand in order to obtain optimal values for power output and fuel consumption.

Two actual p/v diagrams are attached.
One for the previous engine in Diagram 3 and for the reworked engine in Diagram 4.
Here, also, the optimization is evident, even though it cannot be calculated.

Finally, an improvement in the thermal efficiency of 10% should overall be realistic, as in the example given.

Bauck, Herwig, Kreymann
Kraftmachinen, Pumpen, Verdichter (Engines, Pumps, Compressors)
Verlag Handwerk und Technik,
Hamburg, 1977

Helmut Hütten,
Motoren (Engines)
Motorbuch Verlag, Stuttgart, 4th Edition
1978
